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Non-Oxide Advanced Ceramics Widen their Application

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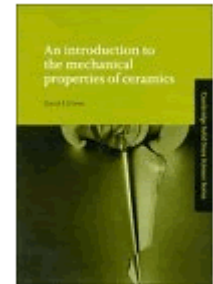


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Background

Advanced ceramics, also termed engineering, fine or technical ceramics, have been used as solutions to many severe material problems over the past 30 to 40 years. Some of these problems involving corrosion, erosion, wear, temperature, electrical insulation etc. (or combinations thereof), have been overcome by the correct selection from a range of materials loosely categorised as oxide or non-oxide ceramics. Those who have found and utilised these solutions have been able to carry out procedures and processes hitherto impossible, resulting in improved yields, life and manufacturing efficiencies of many industrial processes.

Silicon Carbide and Silicon Nitride

The use of non-oxide ceramics has enabled extreme wear and corrosion problems to be overcome, even when there is high temperature and perhaps severe thermal shock involved. Among the established

advanced ceramic materials are Silicon Nitride and Silicon Carbide, both of which offer features that can benefit specific applications.

Silicon carbide is often favoured when there is a need to conduct heat away as it has higher thermal conductivity, while silicon nitride is more likely to be used if thermal shock or other mechanical demands are such that a high thermal shock resistance and fracture toughness are desirable.

Reaction Bonded Silicon Nitride

Silicon nitride exists in two distinct forms. Reaction Bonded Silicon Nitride, designated as Ceralloy 147-1 by Ceradyne Inc, is typically an intermediate strength material as it has 15% to 25% porosity within the structure. The nature of its formation, by the direct nitridation of parts preformed from silicon powder, gives it the characteristic porosity which is extremely fine and tortuous. Under normal conditions, most liquids and gases will not pass through the pores.

The pores are a legacy of the need for nitrogen to penetrate the structure during reaction. This material is densified by reaction rather than contraction and, as such, unlike other ceramics, has no dimensional changes during the firing process. This eases the burden on the manufacturer and can result in avoidance of, or minimal, expensive diamond grinding.

This makes the material suitable for a wide range of jigs and fixtures for heat treatment processes, products for handling molten non-ferrous alloys, chemical engineering processes, welding and cutting processes and many other applications. The material typically has a density of around 2.4g/cm^3 (75% of theoretical) with a strength of 240MPa. Thermal conductivity and expansion are low with high electrical resistivity.

Reaction bonded silicon nitride can fulfil a wide range of demands. However, it is recognised that this grade of material cannot cover the entire spectrum of requirements alone and that a higher strength, more resistant material is needed.

Sintered Reaction Bonded Silicon Nitride

The second form of the material, Sintered Reaction Bonded Silicon Nitride, such as Ceradyne's Ceralloy 147-31N, is fully dense with high strength, 800MPa, no porosity and high fracture toughness (6 to 7.5). These properties are achieved by Ceradyne's unique silicon nitride processing route capable of producing components having complex shapes and in a wide range of sizes.

Applications of Sintered Reaction Bonded Silicon Nitride

Successful usage expands into components which experience high compressive stresses such as cam rollers in diesel engines and other automotive applications (see Figure 1), wear segments on machines for producing paper, chemical, food, pharmaceutical, oil and gas industry valves, seals, rotating parts and wear plates, location pins for projection welding, cutting tool tips, abrasive powder blast nozzles, metal forming tooling, wire and tube drawing and wire guides (see Figure 1). Many of these applications have a customer base using the parts in high volume and for several years problem free.



Figure 1. Automotive components (left) and industrial components (right) made from Ceralloy 147-31N (sintered reaction bonded silicon nitride)

Advanced Ceramics as Alternative Materials

Design engineers, production engineers and mechanical engineers have often compromised on the materials that they have chosen for an application because ceramic solutions have seemed too novel and involve high risk. However, as the range of successful

ceramic solutions grows, the risk element is suppressed. Today, it is often possible to contact the ceramic manufacturer with a new idea for a solution to a problem and to expect that one of a portfolio of materials will have been used successfully in a similar situation.

Ceradyne's Advanced Ceramic Operations has concentrated its market growth around the development expertise of its engineering and production personnel and their outstanding knowledge of nonoxide ceramics.

Other Non-Oxide Advanced Ceramics

Along with silicon nitride, products are manufactured in Silicon Carbide (Ceralloy 146) and Aluminium Nitride (Ceralloy 137), where its thermal conductivity of $150\text{Wm}^{-1}\text{K}^{-1}$ challenges beryllium oxide for substrate applications.

Semiconductor Manufacture

Silicon nitride, silicon carbide and aluminium nitride can be produced in high purity, offering the semiconductor manufacturers products that can survive in the harsh environments experienced in semiconductor wafer manufacture (see Figure 2).



Figure 2. Components for semiconductor processing made from silicon nitride, silicon carbide and aluminium nitride.

Ballistic Armour

Meanwhile, silicon carbide/boron carbide (Ceralloy 546) and titanium diboride (Ceralloy 225) now offer complete ballistic resistance to a very wide range of threats for personnel and

ground, sea and air-based transport (see Figure 3).



Figure 3. Amour vests and helicopter components made from Ceralloy 546 (silicon carbide/boron carbide)

The Outlook

The scale of current advanced ceramic production has reduced manufacturing costs dramatically and what were once seen as very expensive options are now being used on a wide scale. Working together with the ceramic manufacturer, many new applications can be brought to fruition, giving further improvements to efficiency, cost reduction and quality.

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